

IMPERIAL COUNCIL OF AGRICULTURAL RESEARCH

**A summary of some practical results of
sugarcane research in India**



A SUMMARY OF SOME PRACTICAL RESULTS OF SUGARCANE RESEARCH IN INDIA.

PREFACE.

It is no easy matter to survey briefly and yet completely the large amount of research work on sugarcane that has been carried out. There was a substantial foundation in the work done by the Central and Provincial Departments of Agriculture since about 1907. The recent intensification and spread of scientific investigation on sugarcane problems has been largely due to the stimulus and subsidies of the Imperial Council of Agricultural Research.

A chain of provincial sugarcane experiment stations subsidised by the Imperial Council of Agricultural Research now exist—these stations being situated at Jorhat (Assam), Dacca (Bengal), Mushari and now Pusa (North Bihar), Shahjahanpur and Muzaffarnagar (United Provinces), Jullundur and Lyallpur (Punjab), Padegaon (Bombay-Deccan), Anakapalle and Gudiyatam (Madras Presidency), and Mysore. There is also a sugarcane breeding station of the Imperial Agricultural Research Institute at Coimbatore with its branch at Karnal. The first part of this survey is a note prepared by Rao Bahadur T. Venkataraman, Imperial Sugarcane Specialist, on the sugarcane varieties of India and their performances. The second part is a summary under various heads of experiments on various aspects of sugarcane cultivation. The basis of this part is a note prepared by Dr. Burns, Agricultural Expert, and worked up by Rai Bahadur R. L. Sethi, Assistant Agricultural Expert.

It deals with the following points :—

- (1) Improvement in yield.
- (2) Improvement in cultivation methods.
- (3) Rotations.
- (4) Ratooning.
- (5) Manurial experiments including experiments on the quantity and combinations of different nitrogenous manures, time of application and manuring with other elements.
- (6) Green-manuring.
- (7) Molasses.
- (8) Irrigation.
- (9) Soil investigations.
- (10) Pests and diseases.
- (11) Physiological investigations.

VARIETAL

A.—PRESENT POSITION OF SUGARCANE VARIETIES IN THE DIFFERENT PROVINCES.

(1) The United Provinces.

The sugarcane cultivation in these provinces is dominated by the Coimbatore productions which cover about 90 per cent. of the area. Co.-213 occupies the dominant position being grown over 60 per cent. of the cane area in the provinces. Co.-290 and Co.-244 are the next favourites and cover each about 6 per cent. of the total cane area. The new canes that are just getting into cultivation are Cos.-312, 313 and 331 occupying between themselves a further 18 per cent. of the total area under canes. The rest of the area is covered by the indigenous canes like (1) Dhaur, Matna and Kuswar of the Mungo group and (2) Chin and a few others of the Saretha group.

(2) Bihar.

The universal cane in this province also is Co.-213. Co.-210 is a close competitor to it, the relative areas under these two canes varying with the prevailing season. Co.-299 as 'early' cane, Co.-313 as 'mid-season' cane, and Co.-331 as 'late' cane are beginning to spread in the province. The newer canes that are of promise in the experimental stations are Co.-421 and Co.-513 for mid-season Co.-508 as 'early' and Co.-331 and Co.-356 as 'late' canes.

In the interior parts of the province many types of indigenous canes such as (1) Hemja and Bhurli of the Mango group, (2) Lataria and Bhuria of the Saretha group, (3) Nargori and Semari of the Nargori group, and (4) Maneria and Pansahi of the Pansahi group are found, but their importance is limited as between them all they cover only about 3 per cent. of the total cane area.

(3) The Punjab.

Of the major sugarcane growing provinces in subtropical India, this is one in which the Indian indigenous canes are yet cultivated over fairly large areas, as much as 50 per cent. of the total sugarcane area in the province. The climatic conditions of the province are the most severe for sugarcane and the indigenous types—some of them the most primitive in India as well as in the world—are yet grown. The indigenous cane, 'Katha' still occupies as much as 35 per cent. of the total sugarcane area. Of the improved types, Co.-285 is the most favoured and covers an area which is the largest under Coimbatore canes and perhaps equal to that under Katha.

None of the popular Coimbatore productions yield gur of the same quality as Katha and this is responsible for the still comparatively large area under Katha. Other popular canes in the province are Dhau and Lalri among the indigenous canes and Cos.-213, 244, 312 and 313 grown over small areas in particular portions of the province.

(4) Bengal.

Co.-213 is now the dominant cane in the province occupying about 80 per cent. of the total cane area and is steadily replacing Tanna which once covered large areas. Co.-213 is also responsible for appreciably increasing the area under sugarcane in the province as it is able to grow under conditions not quite suitable to the previous canes in cultivation. The province of Bengal has had under cultivation, from a long past, thick and soft canes like Dacca Ganderi, Vendamuki, Shamsara and Puri. It would appear likely that the softer kinds will be gradually replaced by the hardier Coimbatore productions except, perhaps, round cities and for use as fruit.

The indigenous canes of Bengal include Ikri and Khagri. Among the promising canes in the Government Experiment Farms and outside are Co.-281 and Co.-381 as 'early' and Co.-331 and Co.-421 as 'late' canes.

(5) The Bombay Presidency.

This presidency is on the whole a typical tropical cane region and is roughly divisible into two tracts: (1) The Dharwar, Poona and Deccan Canal areas growing real thick canes like Pundia, and (2) the northern tract comprising the districts of Surat and Nasik where the medium canes are apparently quite at home.

The dominant cane in Dharwar, in the environs of Poona and in the canal areas is Pundia. This variety has been holding the field for a long time and over a decade back the opinion was widely held that for Bombay conditions Pundia was hard to beat. The starting of sugar factories and their needs has, however, brought into cultivation other canes that are slowly driving Pundia from the field, either because of their superior yields or greater adaptability to indifferent conditions. The two Java canes, P. O. J.-2878 and E. K.-28, were the first to successfully replace Pundia in the estate plantations. The occasional indifferent environmental conditions associated with large scale plantations discovered the utility of Co.-290 and, in a few instances of even Co.-213, for such conditions. Certain of the Hebbal-Mysore canes, particularly H. M.-320, are grown in such estates. The thicker productions from Coimbatore like Cos.-419; 360 and 417 are proving useful and the first of these has outyielded the introduced Java canes in more than one Experimental Station.

The areas represented by the districts of Nasik and Surat grow, besides the real thick class of canes, canes of medium type like Co.-290; Co.-213 and P. O. J.-213 and indigenous canes of the Sunnaballe group like Khadya. In the district of Nasik the cane Khadya occupies about 70 per cent. of the total area under the crop. The stimulus resulting from the establishment of white sugar factories is not so pronounced in this area.

(6) The Madras Presidency.

This presidency is entirely a tract for the tropical or the thick type of canes. Various canes of this class have been grown for long periods, some of them being introductions into the province almost a century old. A collection of sugarcane, believed to be from Mauritius

and first obtained from a private garden in the Vizagapatam district, proved very useful in fighting out red rot in the Godavari Delta and afterwards spread to almost every part of the presidency and even to the adjacent provinces of Bombay, the Central Provinces and Hyderabad. These, which includes Red Mauritius, Purple Mauritius, and Striped Mauritius, are found in cultivation all over the province. A cane very similar to the Pundia of Bombay is grown in the districts of Coimbatore, Bellary and North and South Arcot.

Fiji B. (Badilla of Australia) which was introduced about two decades back is proving of considerable use in the factory lands at Nellikuppam, but has proved unsuitable in the other parts of the presidency. Another recent introduction, 247-B, from Java, is grown scattered almost all over the province under the name J.-247.

Certain of the medium types like Cos.-213, 290, 281 and 243 have established themselves in places with somewhat indifferent conditions for cane growing, but it would appear likely that such will ultimately be replaced by seedlings of the really thick or tropical types. The Hebbal-Mysore series with H. M. 320 as the most prominent is grown in parts of Salem and Bellary. Among the promising canes of the future are Cos.-413, 419 and 421. Co.-352 has shown a limited range of usefulness in the factory plantations at Nellikuppam.

(7) North-West Frontier Province.

Though situated in the sub-tropical belt, a Paunda cane called 'Peshawar Paunda', which is not dissimilar to the Pundia of Bombay, has been in cultivation in the province chiefly for gur making which is here practised as an art. Owing to its liability to diseases, frost and jackal attacks, it is getting replaced by Co.-290 which is more satisfactory in all these respects though comparatively poorer in quality of gur. This is soon expected to occupy about 70 per cent. of the area in the Northern Circle of the province.

The Southern Circle which is somewhat less important for sugarcane grows at present Co.-290 for gur making and the Paunda cane for chewing purposes. The new canes that are considered promising introductions include Cos.-360, 361, 312, 313 and 412.

(8) Assam.

This province has been growing certain thick types under various local names like Magh, Tel, and Bogapura for considerable time. Exotic varieties from Java, Barbados, Demarara, and Mauritius have been under trial for a fairly long period. The striped Mauritius once rapidly spread in the Brahmaputra valley but later lost ground on account of its liability to lodging and animal attacks. D.-74 and B.-6308 were once favourites. Medium canes like Co.-290 and Co.-213 and thick types like Co.-361 are popular. The new canes of promise are Cos.-419, 408, 411, 413 and 421. P.O.J.-2714, introduced through Coimbatore is proving fairly popular in the province.

(9) Central Provinces.

The canes in these provinces include thick types, like Pundia and a striped variety called Pachrang, and thin canes like Khari (Pansahi group), Kathai and Ledi or Ledu (Nargori group).

The promising Coimbatore canes in cultivation—though but yet limited to small areas—are Cos.-219 and 210 in the districts of Balaghat, Bandara and Chanda, and Co.-237 in Jabulpore and vicinity. Co.-219 is losing its popularity owing to its liability to red rot. New importations are on trial in various experiment stations.

(10) Orissa.

The chewing canes grown in this province include types from the neighbouring provinces of Bengal, Central Provinces and Madras. Mauritius canes including both Red and Striped Mauritius are common in cultivation.

247-B. once largely grown in the Ganjam district, is getting replaced by Co.-213 and Co.-285, the former occupying 80 per cent. of the total sugarcane area in the province. New canes from Coimbatore are on trial and in different stages of filtration.

(11) Sind.

Pundia of Bombay and Red Sport of Striped Mauritius are grown both for chewing and making gur. The Coimbatore canes starting with Co.-213 have just entered the province and are in various stages of trial.

(12) Mysore.

The total area under sugarcane in this State is reported to fluctuate from 35,000 to 45,000 acres according to quantity of water available in tanks. There are two areas in the state growing two different cane types, viz., the Cheni corresponding somewhat to the Sarethia group of the Sub-tropical types and the 'noble' or tropical type. Easily the dominant cane to-day is H. M.-320 which occupies 25,000 out of an aggregate of 45,000 acres. The other canes of promise include H. M.-544, H. M. 553 and H. M.-602. Pattapatti—a striped 'noble' cane believed to be an introduction from South India—once held a dominant position, particularly on better types of land on account of its high juice quality. This is now getting replaced by H. M. seedlings. This is perhaps the only State where the Coimbatore canes have not become dominant. Profuse flowering and consequent low tonnages are the reported defects of most Coimbatore canes under Mysore conditions.

BEHAVIOUR AND DISTRIBUTION OF SUGARCANE VARIETIES IN THE DIFFERENT PROVINCES.

(1) Indian indigenous canes.

Though once the only canes grown in sub-tropical India, these are being rapidly replaced by the Coimbatore productions. Certain types, however, do persist in cultivation in various parts on account of certain special characteristics possessed by them.

Chin.—This cane which was the one taken to Java for crossing with Black Cheribon to breed canes resistant to ' serah ', is now found in fair quantities only in the United Provinces both in the Lucknow division and in the central and eastern duab. Though of poor tonnage, its juice quality and resistance to adverse conditions are responsible for its continuance.

Katha.—A member of the same group as Chin and hardier than Chin. It is still a major cane in the districts of Gurdaspur, Sialkot and Gujranwalla occupying over 30 per cent. of the total sugarcane area in the province. Its resistance to frost and other adverse conditions, coupled with ' earliness ' which results in good quality gur towards the beginning of the cane crushing season in the Punjab, is keeping this variety in cultivation.

Dhau and Dhaul.—These are two similar varieties of the Sunnaballe group found mainly in the districts of Gurdaspur, Sialkot and Gujranwalla of the Punjab and to a very minor extent in the western districts of the United Provinces.

Khadya.—This is a cane of the Sunnaballe group grown chiefly in the district of Nasik where it is liked for its comparative hardiness and good quality gur. It occupies 70 per cent. of the cane area in that district. Other members of this group are found in limited cultivation as far south as Madras Presidency.

Among the Indian indigenous canes which are in minor cultivation in various parts of India, are to be mentioned Lalri, a cane of the Chin group in South East Punjab, Hemja and its allies in Bihar and various representatives of the Pansahi and Nargori groups in the United Provinces, Bihar and Central Provinces.

(2) The thick or ' noble ' type of canes.

In the vicinity of cities and mainly as garden crops in North India and in ordinary cultivation in tropical India, are to be found various canes of the thick or noble type. One important member of this group is the Pundia of the Bombay Presidency closely allied to the Poovan of Madras and the Poundas in various other places. Some of these are grown for gur making in Bombay and Madras.

There is found in parts of Bengal, Assam and North Madras various thick types whose origin is not certain. Some of these are soft rinded and delicate to grow. They include the Bogapura and Magh of Assam, the Gandaries of Assam and Bengal, Vendamuki and Samsara of Bengal and Puri of Bengal and Orissa. The Puri cane is believed to be similar to the famous Creole.

(a) The Barbados canes in India.

Various Barbados canes like B.-147, B.-208, B.-3412, and B.-6308 have and are being grown in certain places. Of these B.-208 occupies, 5,000 acres in the Vizagapatam district of the Madras Presidency and is widely appreciated as a quality cane.

(b) Mauritius canes in India.

The most important Mauritius cane in cultivation in India on date is White Tanna in Bengal and this is fighting a losing battle with Co.-213 in

the province. During 1936-37 it covered 36,000 acres in Bengal against the 3½ lakhs acres under Co. 213. The other Mauritius canes include Striped Mauritius, and Red Mauritius which are to be found in occasional cultivation in Madras, Bombay and the Central Provinces. Mention needs to be made of Purple Mauritius which occupies 10,000 acres in Vizagapatam district of the Madras Presidency. Bud sports are somewhat common in these canes and two such attained some commercial importance.

(c) *The Java Canes in India.*

In the past there were importations of Java canes into India and the useful ones are now confined principally to the Madras and Bombay Presidencies. Perhaps the most important of these is P. O. J.-2878 which is showing very good performance in the factory lands of the Bombay Presidency. Both E. K.-28 and to some extent P. O. J.-2883 are also found in Bombay. 247-3—often known in India as J.-247—in the Northern and Central districts of the Madras presidency and P. O. J.-2714 in Assam are others that have proved useful.

(d) *The New Guinea canes.*

Of particular interest is a cane from Australia called 'Badilla' in that country and 'Fiji B' in parts of Madras. This is a very thick juicy cane and has shown marked usefulness in an isolated factory plantation in the central districts of the Madras Presidency. This cane is reported to be growing wild in New Guinea to this day. Attempts to introduce it elsewhere in India have not been successful so far.

(3) **Seedling canes of Indian origin.**

(i) **HEBBAL-MYSORE CANES.**

The Sugarcane Breeding Station, Hebbal (Mysore), has been raising seedlings mainly of the 'noble' type and some of these have got into cultivation chiefly in Mysore, to some extent in parts of Bombay and are under trial in parts of the Madras Presidency.

H. M.-320.—At present this is the most widely cultivated of the Hebbal-Mysore series occupying more than 25,000 acres in Mysore state and is in cultivation in parts of Bombay as well.

H. M.-544 and others.—This is a seedling which is in cultivation not only in Mysore but in parts of Bombay occupying 600 acres in Dharwar. This is getting replaced now by H. M.-320. The other H. M. seedlings of promise occupying limited areas in the State or under trial outside include H. M.-87, H. M.-89, H. M.-360, H. M.-602, H. M.-603, H. M.-608 and H. M.-609.

(ii) **COIMBATORE CANES.**

(a) *Coimbatore canes in general cultivation.*

Co.-213.—This is easily the most universal cane bred at Coimbatore and is, therefore, mentioned first. It dominates the sugarcane areas in the United Provinces, Bihar, Bengal and Orissa. For the time at any rate, it is proving of value under somewhat indifferent conditions in most parts of tropical India as far south as South Madras.

The cane stands a wide range of conditions from drought in Western Sub-tropical India and elsewhere to water-logging in Bengal. Its chief points are vigour, i.e., tonnage, good habit and ability to grow under indifferent conditions. It is somewhat susceptible to salinity in soil and liable to take red rot. It has shown smut both in the Bombay and Madras Presidencies. It covers the land during the early stage of growth thus suppressing weeds. Though in gur quality it is not equal to the canes it has been replacing it has spread because of its appreciably heavier yields and its ability to stand somewhat indifferent cultivation. A thick cane of Java, an acclimatized thick cane of Madras, the Indian cane Chin, and the Coimbatore form of the weed *S. spontaneum*, which stands both drought and heavy waterlogging, are all included in its ancestry.

The rest of the canes of the Coimbatore series will be mentioned below numberwar.

Co.-205.—This seedling is remarkable as a plant of the F_1 generation that has proved useful in field cultivation. It is a direct cross between the noble cane Vellai of Coimbatore and a wild type of *Saccharum* (*S. spontaneum* of Coimbatore).

Its first and pronounced success was in the Punjab where it stood out prominently above the poor class of indigenous canes of the province like Katha and Dhaulu. Once popular under adverse conditions in practically the whole of Sub-tropical India, it is being rapidly replaced by a later and better cane, Co.-285. This cane is resistant to salinity in the soil, drought and heavy water-logging. Under heavy water-logged conditions it shows a good habit with straight canes and satisfactory juice quality. Having served its purpose it is likely to gradually disappear from cultivation. It has high fibre and very impure juice and certain of the white sugar factories are now refusing to take it. It has recently been removed from the list of approved canes in the Punjab.

Co.-210.—*Bihar.*—This is a comparatively hardy type which is proving a close rival to the universal cane Co.-213 in North Bihar. It stands drought and rapidly bucks up after monsoon rains. It is a mid-season cane not arrowing freely in Bihar. It prefers a light soil and can grow with less water than Co.-213. It is fairly susceptible to both water-logging and soil salinity.

Central Provinces and Berar.—In the Central Provinces it is liked for its good yield, ratooning capacity and comparative freedom from animal attacks. It is susceptible to smut, possesses an unsatisfactory habit under Central Provinces conditions where the gur is also reported to be saltish and of inferior quality. It arrows freely in the Central Provinces. The cane has shown limited use in Assam.

Co.-214.—*Bihar.*—This is a cane which in the earlier years was much appreciated by the factories in Bihar for its earliness. Though the rind is very hard certain Bihar factories offered a premium for this cane on account of its earliness. It has a bad habit that results in curved and cooked canes difficult to place on the hoppers. It is susceptible both to drought and salinity in the soil. The area under this cane is contracting in Bihar because of the later Co.-299 which is equally early and cuts higher tonnage.

Its juice quality is such as to be once selected by Shahjahanpur as a useful type. It did not, however, become popular, because of its poor tonnage. One very important characteristics of this cane is its very high resistance to mosaic. This disease has not yet been noticed on this variety under field conditions.

Co.-244.—West United Provinces.—The utility of this cane was first discovered in the western districts of the United Provinces (in Meerut). This is essentially a variety adopted to conditions of scant manure and waterings. The discovery of the merits of this cane was somewhat accidental and is attributed to a grower planting it on one of his poorer lands. In the western districts of the United Provinces it ripens earlier than Co.-213 and is practically free from mosaic in both plant and ratoon. It lodges badly when well manured and is in consequence affected by frost at Karnal. It is best to cut this cane by end of January latest under the United Provinces conditions as it develops appreciable fibre later. In the United Provinces it is of considerable use occupying about 9 per cent. of the total area under cane in those provinces.

Punjab.—From the western districts of the United Provinces this cane spread to the poorer lands in South East Punjab without departmental intervention and the factories there prefer this cane to Co.-285 for milling. Its cultivation is restricted to West United Provinces and South East Punjab.

Co.-281.—This is a cane which, though bred for India, has proved more useful in foreign countries. It is in cultivation in Natal, Louisiana and Cuba. In Florida it has been reported as suitable for heavy water-logged conditions.

In India itself its utility is confined mainly to the factory area in the South Arcot district of the Madras Presidency where, under certain conditions, it has out-yielded the very much thicker cane 'Badilla' or Fiji B. It is also reported doing well in the west paddy lands of the Tanjore delta. This is an early cane of high juice quality. For white sugar manufacture by the open pan system it has proved easy to work and yields high quality sugar.

Co.-285.—Punjab, etc.—This is a fairly universal cane in the Punjab on account of its resistance to frost and comparative freedom from the major pests and diseases. It has proved resistant to both drought and water-logging. This is a cane of fairly high fibre and comparatively low juice quality and hence not a favourite with the mills. It is rapidly replacing Co.-205 in the Punjab. This cane has entered into general cultivation in Orissa and has shown some use in the Tanjore delta of the Madras Presidency.

Co.-290.—This is another cane which is very popular in foreign countries; Natal, Louisiana and Australia.

United Provinces.—This is a fairly popular cane in this province occupying about 9 per cent. of the total sugarcane area and is particularly popular in the districts of Rohilkand and Lucknow, the home of the Khandsari industry. It is favoured by this industry because of its comparative softness which give a good extraction even from bullock driven mills. It is a heavy yielder in the United Provinces with a juice quality

better than Co.-213, but distinctly inferior to it in habit and liability to animal attacks.

North-West Frontier Province.—This cane is also popular in the North-West Frontier Province occupying 70 per cent. of the cane area in that province. It is liked in the province for its resistance to frost, drought and animal attacks as compared to the local Pounda. It yields twice that of Pounda and ratoons well. It costs less to grow than the local Pounda. Its gur, however, is inferior to the Pounda in taste and keeping quality.

Bombay.—In the factory plantations of Bombay it has been of considerable use for growing on land in which the thicker and better class of canes would not grow. The gur of this cane is inferior to Pounda and this has restricted its spread in areas devoted to gur production. It is also somewhat popular in the Nasik district of the Bombay Presidency. It has entered into general cultivation in Assam.

Co.-299.—Bihar.—The use of this cane is confined to Bihar and as an 'early' cane to replace Co.-214 by its distinctly heavier tonnage. Showing a purity of 85 per cent. in early December, it maintains this figure without serious deterioration till March, a character which is much appreciated by the industry.

Co.-312.—The United Provinces.—This cane first became popular in the United Provinces on account of its heavy yields ripening earlier than the standard cane Co.-213 and producing good quality gur and sugar. It is fairly resistant to water-logging, but lodges badly, arrows profusely and is susceptible to both mosaic and insect pests. It is the heavy yield of this cane that is keeping it in cultivation.

Punjab, etc.—This cane is popular in parts of the Punjab also for the characteristics above mentioned. For this province its susceptibility to frost is an additional disadvantage. While capable of growing with comparatively less water and on poorer lands, it responds quickly to better cultivation. This cane is coming into favour in Sind on account of its heavier yields.

Co.-313.—The United Provinces.—This is another recent favourite of the United Provinces and is liked for the combination in it of earliness, high sucrose, and heavy yield. Its gur and sugar are of high quality. It is, however, susceptible to mosaic and this is likely to prevent its wider extension into cultivation.

Punjab, etc.—Under Punjab conditions it is found to keep its quality till late in the season. Both quality and recovery of sugar are high as compared to other canes like Co.-285. The two defects of this cane for Punjab conditions are its susceptibility to heavy frost and the deterioration of planting material, when pitted during the winter months as a protection against damage by frost. It needs a moderate amount of irrigation. This cane is slowly working into cultivation in Bihar and is reported promising from the Experimental Stations in Bombay, Sind, the Central Provinces, Madras and North-West Frontier Province.

Co.-331.—Bihar.—This cane often attracts attention in trial plots by its quick erect growth. In Bihar it is getting into general cultiva-

tion, but the factories are not in favour of this cane because of (1) want of uniformity in its performance, (2) the development of a central pith later in the season, and (3) the fear that the growers may pass it for Co.-213 during mid-season when the sugar values of a late cane like this would be comparatively low. It is fairly resistant to water-logging.

The United Provinces.—In the United Provinces it is somewhat popular because of its heavy yield, erect habit, quick growth and late maturity. It resists *Pyrilla* and borers to some extent. It is not a favourite with the factories because of the development of pith later in the season.

(b) *Coimbatore canes of promise or beginning to get into cultivation.*

Of these Cos.-419 and 421, both bred at the Thick Cane Section of the Coimbatore Station are the most outstanding.

Co.-419.—*Bombay.*—This is a hybrid between P. O. J.-2878, the wonder cane of Java, and the medium cane Co.-290, which has shown considerable use both in India and in foreign lands. It has given very heavy yields and gur of superior quality in the Bombay Experiment Stations and has come out first in the trial plots. It is satisfactory both in habit and ratooning capacity and has been distributed into general cultivation in the Bombay Presidency. Favourable reports are being received from the growers.

Madras, etc.—It has shown very heavy yields in all the experiment stations of Madras, and demonstration plots with this cane have been started in the cultivators' fields in that Presidency. It has shown good performance in the experiment stations of Assam and Baroda.

Co.-421.—This is, at present, the most promising of the new canes of the thick medium type and has rushed to the first rank in many experiment stations in sub-tropical India.

It is being rapidly multiplied for distribution in the Experimental Stations of Bihar and has shown higher yields than most of the preceding medium types in the Punjab and Orissa. The variety is under demonstration in the cultivators' fields in Madras and is occupying large areas in the Experimental Stations at Dacca, Sakrand, and is grown in every Experiment Station of the United Provinces as a cane of promise.

Co.-360.—*Bombay.*—This cane, which is higher yielding than *Pundia* and ratoons well, has been distributed into general cultivation, in the Bombay-Deccan canal area. It arrows but sparsely unlike many other Coimbatore seedlings which arrow rather freely and are in disfavour on that account. Good reports have been received from the factory plantations about its performance and has proved distinctly superior to *Pundia*.

It has given gur of excellent quality in the North-West Frontier Province and has been found to ratoon well in parts of Madras.

Co.-413.—Fairly large areas are under this cane in the Experimental Stations at Patna, Kopargaon and Padegaon and the results have been

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quite satisfactory. It has been found promising in cultivators' fields in Surat as also in the districts of Salem and Coimbatore in the Madras Presidency. In these two districts it is showing itself superior to both Co.-213 and Co.-290 which are in partial cultivation in the tract.

(c) *Other canes of minor importance.*

Cos.-300 and 350 are grown to a minor extent in parts of the United Provinces, the first for its erect habit and the second for its early maturity.

Cos.-352 and 356 are found in small plots, the former in the factory zone at Nellikuppam in the Madras Presidency and the latter in the district of Gorakhpur in the United Provinces.

Co.-237 is showing some usefulness in the northern circle of the Central Provinces and Co.-243 in one of the new factory areas in the Kistna district of the Madras Presidency.

Co.-223 which was once popular in parts of Punjab is losing ground because of its liability to mosaic and other diseases. Co.-219 is another cane which was once of some use in parts of the Central Provinces, but is now getting into disfavour.

Among other canes of some promise are :—

- (i) Co.-381 as a possible 'early' cane for Bengal.
- (ii) Co.-385 as a possible 'early' cane in the United Provinces, and
- (iii) Cos.-402, 407, 408, 412 and 417, all thick types and showing promise in the experiment stations of the Bombay and Madras Presidencies, Assam and North-West Frontier Province.

E.—SUMMARY OF THE VARIOUS ASPECTS OF SUGARCANE CULTIVATION.

I.—Improvement in yield.

While the yield of great tracts of the main sugarcane producing provinces was still far from satisfactory when compared with the yields got, say, in Java, it is a definitely proved fact from the work of the Indian research stations and also from the experience of those factories which grow their own cane that high yields are possible. The following few sample figures indicate the range of possibilities.

In Assam in 1932-33 the average outturn per acre of the experimental crop of all varieties was 28.26 tons of stripped cane for plant cane and 26.67 tons for ratoon. In 1935-36 the new varieties namely, Co.-364, Co.-408, Co.-411 and Co.-413 gave an outturn of a little more than 40 tons of stripped cane per acre whilst Co.-419 gave an outturn of 54 tons stripped canes per acre—the highest outturn ever recorded at the Jorhat farm. At Gudiyattam in 1935-36, Co.-213 gave 58.9 tons cane per acre.

Experiments conducted with Co.-360, and POJ-2878 at three sugar factories, one Government farm and three cultivators' fields in different parts of Deccan-Canal area in 1935-36 gave the following results :—

Yield per acre in tons.

Name of place.	Co.-360.	POJ.-2878.
Ravalgaon sugar factory	50.5	41.4
Kalamb sugar factory..	61.5	48.0
Belbandi sugar factory	44.48	43.47
Kopergaon farm	38.00	36.26
Pravara canals	39.00	37.00
Godavari canals	48.00	49.51
Nira left bank canal	43.7	44.6

In 1935-36 at Padegaon, Co.-419 gave 62.59 tons per acre. In a competition organised by the Maharashtra Chamber of Commerce, Bombay (1935-36) yields of 80 to 100 tons per acre were obtained without any reduction of sugar. At Dacca in 1935-36, Co.-432 yielded 31.9 tons and D.S.-31 gave 36.1 tons.

In Mysore in 1935-36 in separate experiments HM-320 gave the following yields :—

32.59 tons per acre.
 36.86 tons per acre.
 27.80 tons per acre.
 HM-606 51.58 tons per acre.
 37.69 tons per acre.
 and HM-607 42.81 tons per acre.
 50.43 tons per acre.

In the Punjab by judicious cultivation, manuring, irrigation, and selection of varieties the highest yield of *gur* on 1/40th of an acre piece at Risalewala was increased to 159 maunds (approximately 5.8 tons) per acre.

II.—Improvement in cultural methods.

(a) *Methods of planting.*—A few important standard methods of cultivation are (i) the Manjuri Method, (ii) the Pusa Method and (iii) the Shahjahanpur Method. In the Manjuri Method first ploughing is done deep by the iron gallows plough and the cane is planted in furrows from three to four feet apart early in January with a dressing of 150 lbs. of nitrogen applied three times half in the form of sulphate of ammonia and the other half in cake in addition to previous green manuring. The set rate per acre is about 10,000 setts and interculture is done between the rows of cane with a view to conserve moisture, remove weeds and bring the soil to the optimum physical condition. The Pusa Method consists of planting by the ridge and furrow method instead of in trenches. The furrows are opened out 2½ to 3 feet apart, the distance between rows varying according to varieties—3 feet in case of medium and thick and 2½ feet for thin canes, the depth of the furrows depending upon the kind of soil and the season of planting. A double mould-board plough is most useful for this purpose. It should have a sub-soiler attached to it to loosen the sub-soil in the furrow and so make it easier for the young rootlets to establish themselves. A combined gatherer

and roller is then drawn over the furrows filling them up covering and pressing the sets. The set rate per acre depends on the variety ranging from 14,000 for Co.-213 to 17,000 for Co.-214 per acre. The sets are placed eye to eye and doubled at the furrow ends after the Java fashion. The sets before planting are soaked in coal-tar water to provide temporary immunity against white ants. The Shahjahanpur Method consists of growing cane in trenches four feet apart—more or less after the Java method of cultivation. The trenches are dug in November and cane is planted in February. Organic manure in the form of farmyard manure is added in the beginning and inorganic manures such as ammonium sulphate at planting time or at earthing. In addition green manuring is done in August. The crop is intercultured about twice after each irrigation with a hand hoe.

These methods have been modified in their respective tracts in the light of experience gained from recent researches. As a result of the Padegaon scheme the important modifications to the Manjri standard method for 'B' type of soil are substitution of green manuring for manuring with farmyard manure, application of 100 lbs. of P_2O_5 to cane at the time of planting, increase of 150 lbs. of nitrogen dressing to 225 lbs. and change in the time of application of these manures, i.e., application of sulphate of ammonia at the time of planting instead of after three weeks. The suitable rotation for the 'B' type of soil has been found to be cane, cotton and sann against cane, *nilwa* and *sann*. Experiments to compare the Pusa Method of furrow planting with that of trench planting for two years at Musherī (Bihar) confirmed the superiority of the former method and effective improvements were introduced in the manurial programme of the former method. At Shahjahanpur (U. P.) cultural trials conducted for four years (1932-36) indicated that in fertile land the highest yield was obtained in trenches, the next highest on the flat followed by earthing in the rains and the least yield on the flat without earthing. In poorer fields, on the other hand, flat planting with three feet spacing followed by earthing showed better results than planting in trenches four feet apart. The crops did not require to be earthed up on poorer land as the growth was not heavy and there was little danger of lodging. On fertile lands, however, due to the heavy growth of cane, earthing was essential to save the crop from lodging. Trenching was more suitable for lighter lands and flat sowing for heavy areas. In the Punjab two years' trials at Risalewala to compare the indigenous method of planting in furrows one foot apart made by the country plough with (i) planting on the flat two feet apart and ridging up when rains set in, and (ii) planting in trenches two feet apart followed by earthing during the monsoon did not show any material difference in yield, but at Julundur the two latter improved methods gave significantly higher yields over the local method and were more advantageous in that the crop did not lodge and the post-sowing cultivation operations were carried out more easily and cheaply by bullock power.

(b) *Time of planting*.—Trials conducted at various places showed results definitely in favour of early planting. In Madras trials for finding out the most suitable season of planting cane showed that canes planted in (a) February to May gave the highest yield within ten to twelve months and (b) those planted in September gave a very good tonnage but the crop took over 15 months to mature. At Palur (Madras) in 1934-35 monthly trials showed January-April to be the best season for planting. In the United Provinces at Shahjahanpur in repli-

ated experiments were conducted for three years (1932-35) to find out the most suitable time for planting and the best portion of cane for sowing. Planting was done in the four months of January, February, March and April. Results indicated that the earlier planting, i.e., in January and February was definitely better than planting in the last two months. Sowing in the end of January showed the best result both as regards percentage of germination of buds and total yield. The portion of cane did not matter much during earlier plantings but when planting was done late top portions of cane showed the best result. Experiments conducted at Gorakhpur (U. P.) for two years to compare autumn (October) and spring (February-) sowing did not show any special advantage of autumn sowing over spring sowing so far as the yield was concerned but the autumn sown crop was earlier in ripening and was better in percentage sucrose and in purity than the spring crop. In Assam, sugarcane planting in October just after the close of the rains was found to give higher yields than that planted in the normal season, the figures of stripped cane per acre being as follows :—

October planting lbs.	June planting lbs.	March planting lbs.
70,362	42,498	36,504

In North Bihar, early planted cane scored an advantage over the late planted one if sown after January. At Risalewala (Punjab) early planting showed good results in a trial in which sowings were done fortnightly from the beginning of March to the beginning of May. Germination counts of these are given below :—

Sowing time.	Percentage of germination.
1st week of March	40.2
3rd week of March	56.8
1st week of April	33.8
3rd week of April	22.8
1st week of May	16.6

At Jullundur results were similar and autumn planting as compared to spring planting did not show any great difference in yield. In Mysore HM-320, HM-612, HM-614, HM-619 and HM-627 when planted in June and July and harvested after 15 months gave a high yield of 50 to 60 tons per acre. The juice quality was not very high probably due to the advent of the monsoon which depressed to a certain extent the quality of the juice. November to January planting gave the richest juice while December planting gave the highest yield. September and October plantings gave poor yields due to rotting of the eye buds from excessive rain in their early stages of growth. Canes planted in February and March were ready for harvesting after 12 months and they could be kept on in the field for another period of two to three months without appreciably affecting the keeping quality. In the N.-W. F. Province (1935-36) in an experiment to find the most suitable time for planting, planting during the first week of March gave better results than planting by the end of March.

(c) *Distance between lines, i.e., spacing.*—This depends on the variety and the condition of fertility of the soil. These varieties generally require small distance than the thick ones and fertile lands give better yield with distance 3 ft.—4 ft. than barren lands where distance may vary from 2 ft.—3 ft. In Bihar the optimum distance between rows was found to be 2½ feet in the case of early varieties and three feet in the case of mid-season and late varieties. Wider spacing, though it resulted in a large number of stalks was found uneconomical from the point of view of acre yields of cane and sugar. In Assam, in an experiment with three different spacings, i.e., three, four and five feet between rows of two different varieties, POJ-2778 (thick cane) and Co.-210 (thin cane), maximum outturns were obtained with three feet spacing with a thin variety and with both three and four feet spacing with the thick variety. Four feet distance is recommended for thick varieties to facilitate inter-cultural operations. At Shahjahanpur results of experiments carried out for three years (1932-35) showed that the poorer the fields the better was the result if the distance was smaller. In fertile fields on the other hand the yield increased with increased distances. In poor lands the crop should be sown on the flat without earthing up and with the lines closer together, the distance to range from 2½ ft. to 3 ft. depending on the amount of manure available, the less the manure the smaller may be the distance. In land of medium fertility the distance should range from 3 ft. to 3½ ft. followed by earthing and in rich fields when a large quantity of manure was added and irrigation was ample it was always better to sow the crop in trenches four feet apart. The quality of juice deteriorated with increasing fertility but there was no effect of spacing on the quality. At Anakappalle in 1934-35 results from spacing trials were not significant in all the varieties but a slightly wider spacing seemed to be advantageous. In 1935-36 the general trend of the experiments was that, within a variety, yields were in general greater under a closer spacing but the differences were not significant. In the N.-W. F. Province (1935-36) in an experiment with *Poundah*, planting at three feet apart in ridges gave a better result than planting four feet apart.

(d) *Seed rate per acre.*—This depends chiefly on the variety and to some extent on the time of planting. Thicker varieties and earlier planting generally require a smaller number of sets than thinner varieties and late planting. In late planting, generally due to unfavourable weather conditions some of the sets fail to germinate and hence a larger number of sets is required—12,000 sets per acre on the whole seems to be a good rate for an average Co. variety. In Madras great saving has been effected by reducing the seed rate from 20,000 to 25,000 sets per acre, as was previously given by the cultivators, to 12,000 to 16,000 sets per acre as a result of experiments carried out at Anakapalle (1934-36). In the Punjab 40,000 sound sets per acre (each set of two eye-buds) were found necessary to get a good stand of the crop. At Muzaffarnagar (U. P.) in a complex experiment of seed rate plus spacing closer spacing (2½—3 feet) with seed rate at 10,000 to 12,000 sets per acre gave better yield than 80,000 sets with 3½ feet spacing.

(e) *Germination.*—Preparation of seed bed according to local conditions of the soil, shallow planting, and selection of good planting material are the essential requisites of good germination. Initial soaking of sets and application of ammonium sulphate mixed with equal quantity of dry

earth at the time of planting was found conducive to increased germination. Generally top portions of cane gave greater percentage of germination than either bottom or middle portion more especially in adverse conditions of either climate or soil.

In Bihar experiments carried out for two years showed that soaking of sets before planting stimulated quick and full germination and resulted in heavier subsequent growth. At Pusa, as advocated in the Pusa Method, sets soaked in coal-tar water provided a temporary immunity against white ants. To make this coal-tar mixture about a gallon of water was boiled with about ten drops of coal-tar added to it (just sufficient to give the water some coal-tar smell) keeping it well stirred. When the mixture was cool sets were immersed in it and taken out for immediate planting. Care was taken that no free tar remained in the dipping mixture lest it injured the cane eyes. At Maseri coal tarring of sets afforded little protection against white ants while it adversely affected germination. At Padegaon experiments carried out for five years (1932-37) showed that temperatures below 50 F. delayed the germination greatly and lowered the percentage success of the eye-buds planted. The plants were less vigorous and were thus susceptible to the borer attack. Eye-buds with dry scales germinated very slowly and an elimination of these buds resulted in high percentage success. In fact this was found to be one of the most important factors in the great variability of the germination capacity of different varieties. Proper management according to the local conditions of the soil was also found important for good germination. With heavier soils dry planting with light irrigation resulted in the highest germination. The essential factor was shallow planting at a depth of one or two inches and in the case of deeper embedding with the sets, skipping of one or two irrigations after the initial soaking, was conducive to increased germination. Previous cultural operations specially nitrogenous manuring on the cane used for planting were found to be very important. Application of sulphate of ammonia at the time of planting increased the velocity of germination and this effect was more pronounced in the case of adverse conditions of either climate, soil or the planting material. Top portions of the canes of both POJ-2878 and Pundia gave greater percentage of germination than bottom and middle portions. No variation was observed in germination capacity between one-eye-bud and three-eye-buds sets. The crop of one-eye-bud sets was however less vigorous with smaller leaf area than that of three-eye-buds sets and with lower manurings this difference was reflected even in the final yields. It would thus be seen that the nature of the sets not only exerted great influence on the germinating capacity of the eye-bud but also on the growth of the plant and final yield and that proper selection was thus extremely important. At Muzaffarnagar (U. P.) application of sulphate of ammonia to the germinating sets proved deleterious in dry soil but was helpful in moist land. In North Bihar the viability of buds was adversely affected when they came in direct contact with the artificial manures. It was therefore recommended to mix the manures well with soil in the open furrows before planting.

(f) *Inter-culture*.—Inter-culture or hoeing is one of the most important operations in sugarcane culture. It not only helps nitrogen fixation and accelerates the growth of nitrifying bacteria but helps in the conservation of soil moisture and is a great check on the growth of weeds. The main period of nitrogen fixation in sub-tropical India is from March to June

and hoeing is therefore chiefly recommended during that period. In an experiment carried out at Shahjahanpur (U. P.) for three years when different depths of hoeing, i.e., surface hoeing about 1 in., shallow 2½ in. and deep 4 in. were combined with the number of hoeings (1, 2 and 3) after each irrigation it was found that inter-culture was very necessary for obtaining good yield, depth of hoeing being more important than the number of hoeings. Two deep hoeings after each irrigation showed the best results. The quality of juice was not affected either by the depth or number of hoeings. In the North-West Frontier Province (1935-36) in an experiment to compare the cultivation of a bullock hoe with that of a *Deshi* (country made) hoe, cultivation by the latter was found better.

III.—Rotational trials.

The following up of a cane crop too closely by another cane crop tends to exhaust the land. Green-manuring the land with *sann* previous to sowing the crop supplemented with additional manuring with nitrogen in the form of cake or ammonium sulphate at the time of planting has generally been found very useful. At Madras in 1930-31, a rotation experiment at Palur continued for eight years showed the results in favour of wider rotation. The yields of cane of the four, three and two years rotations were 33.74, 29.28, and 24.32 tons per acre respectively. At Pusa in 1933-34 and 1934-35 manurial and rotation experiments were conducted with the object of maintaining the land in the best possible condition for a close cane rotation such as cane-fallow-cane. The following five treatments were given in 1931-32 to the cane crop :—

- (1) fallow in *kharif* and fourteen tons farmyard manure applied at the end of the monsoon,
- (2) fallow in *kharif* and complete minerals (40 lbs. N. as ammonium sulphate, 52 lbs. P_2O_5 as super-phosphate and 40 lbs. K_2O as potassium sulphate) applied at the time of planting,
- (3) *sann*-hemp sown in *Kharif* and ploughed in after eight weeks with 50 lbs. P_2O_5 as superphosphate, 50 lbs. N. as rape-cake applied at the time of planting,
- (4) *sann*-hemp sown in *Kharif* and ploughed in after eight weeks, complete minerals (as in treatment No. 2) applied at the time of planting, and
- (5) fallow in *kharif* and standard manure (40 lbs. N. as rape-cake and 50 lbs. P_2O_5 as superphosphate) applied at the time of planting. Treatment No. 1 gave the highest yield followed by treatment No. 3 while treatment Nos. 4 and 5 gave almost similar results to those of treatment No. 2. Similar results were obtained in 1934-35.

At Padegaon the rotation adopted is cane, cotton, *sann* and was mainly intended for the study of the residual effect of the various manurial treatments on cane. In cotton no residual effect of 75 and 150 lbs. nitrogen on the previous cane was visible but 300 lb. nitrogen did have an effect while the residual effect of superphosphate was observed even in the *sann* hemp crop taken in the third year after cane.

In Assam a rotational trial is in progress for the last three years for both thin and thick canes on both plant and rotoon canes on two plots

of land whose fertility was actually ascertained before by two uniformity trials. The rotation included four different treatments (a) green manure with a phosphatic dressing followed by a *rabi* crop in the winter, (b) green manure alone followed by a *rabi* crop in the winter, (c) occasional cultivation similar to (a) and (b) with phosphatic dressing but without any cropping, (d) fallowing (resembles mostly cultivators' practice). The general plan was to grow plant and ratoon canes in the first and second years under all treatments separately for the two varieties. Up to now (a) is considered best and is at present being followed on the farm. At Muzaffarnagar (U. P.) a rotational experiment to compare the effect of the following two rotations on the yield of plant and ratoon cane using three kinds of organic manures, i.e., neem cake, farmyard manure and molasses each to supply 70 lbs. of Nitrogen to the plant cane and $2\frac{2}{3}$ of that quantity to the first ratoon crop is in progress.

(a) Sugarcane—1st Ratoon—Wheat—Cotton (four years).

(b) Sugarcane—1st Ratoon—Wheat—Sannai (ploughed in). (Four years.)

The results so far obtained show that the cane crop does better after *sannai* than after cotton, molasses on account of its transport cost was uneconomical to apply. At Shahjahanpur as a result of experiments conducted for many years the following two rotations for two types of soils, i.e., light and heavy are practised

1. Sugarcane—wheat—gram—sugarcane—four years on lighter areas.
2. Sugarcane—wheat—sugarcane—three years on fertile heavier areas.

IV.—Ratooning.

Ratooning is a subject on which there has been a good deal of controversy particularly since there is some evidence that ratooning causes an increase in insect pests. The period of profitable ratooning varies greatly in different localities and depends on the soil, variety and the treatment which the crop receives. Ratooning as at present practised has a bad name perhaps because the crop is often neglected. In that condition the decaying vegetable matter affords a breeding place for insects and a ratoon crop is thus rightly looked upon as a source of infection. Canes differ to some extent in their performance as plant canes and as ratoons. On the whole thin canes are better suited for ratooning than thick canes although thick varieties have also been found to ratoon well in certain places. In an experiment in Dombay in 1932-33 POJ-2878 gave best results as ratoon, EK-28 coming next as compared to other varieties. In the Punjab in 1934-35 Co.-273 did not ratoon well but Co.-223, Co.-205 and Co.-285 ratooned well for a number of years. Experiments at Anakappale in 1935-36 indicated that Co.-243 did well in both ratoon and plant crop closely followed by Co.-281. There was a greater amount of pyrilla attack in ratoon crop in wet land than in the planted crop. At Samalkota the trials indicated that thin canes were better suited for ratooning than thick canes. In Madras at Palur the same year an experiment to test the value of ratooning showed that saving in the cost of cultivation was not commensurate with the loss in yield. At Jorhat (Assam) in a preliminary trial with ratoon canes C.-407 gave the highest outturn both in respect of yield of cane and total sucrose followed in order by C.-410, Co.-408 and Co.-413. Co.-407 in this case gave 29.19 tons cane and 3.46 of sucrose per acre. (Table V.) Manurial trials

conducted with ratoons (1934-35 and 1935-36) brought out clearly the necessity of manuring the ratoon crop. A mixture of 200 maunds cowdung and 2,000 lbs. oil cake per acre was more efficient than either cowdung or oil cake applied alone. At Shahjahanpur (U. P.) Co.-185, Co.-331 and Co.-213 ratooned well and experiments to find out the behaviour of other varieties are in progress. One ratoon effectively manured and hoed is usually considered sufficient. Two are only rarely recommended under very highly fertile conditions. The crop should be treated like a plant crop with regard to operations like irrigation, manuring and hoeing.

The Sugar Committee of the Imperial Council of Agricultural Research, (July 1936) considered the views on ratooning of the Directors of Agriculture in Provinces and States and of factory owners and cane growers. Opinions were divided as to the increase of insect pests in cane and it was considered essential to find out the exact effect of ratooning by scientifically planned experiments. The matter is receiving the attention of the Imperial Council of Agricultural Research.

V.—Manurial

Summing up of these trials is a difficult matter as manurial experiments were planned differently at each station to suit their local requirements. Almost every station has used different combinations and quantities and it had naturally to be done so as the soils, climate varieties and systems of agriculture of various places require different types of manuring. The later experiments have mostly carried out on in replication and the results have been interpreted statistically. The term 'significant' in these trials means that the results obtained were not accidental but were really due to the treatment applied. The subject matter of this chapter can be dealt with more conveniently under different heads, of quantity, combination, time of application of manures, etc.

(a) *Quantity*.—In tropical India, *e.g.*, Bombay, Madras, Mysore, etc., where thick varieties can grow, a very large quantity of nitrogen to the extent of 300 lbs. to 600 lbs. of nitrogen can be given although the Pade-gaon results show 150 lbs. nitrogen as top dressing in addition to green manuring as the optimum dose under normal conditions. An interesting attempt to force up yields resulted from a competition organised by the Maharashtra Chamber of Commerce, Bombay, in 1935-36. Various of the Deccan factory estates competed and yields of 80 to 100 tons per acre were obtained without any reduction in sucrose with heavy manuring combined with suitable watering but the effect of such heavy yields on the soil is still to be investigated. Such heavy yields are not possible to obtain in Northern India where early setting of cold in October has an inhibitory action on growth. Only thin and medium varieties are suitable and experiments have shown that 100 to 120 lbs. nitrogen is the optimum rate per acre. Manuring with additional nitrogen helps in higher tonnage but the crop shows luxuriant vegetative growth and delayed maturity. Again much depends on the condition of the land to which the manure is to be added. Poor light loam will certainly require more food than well-worked fertile land. Poor soils generally respond readily to increasing quantities of nitrogen. It may, however, be pointed out that in order to take full advantage of modern knowledge concerning crop growth it is absolutely necessary that the important point of proportion should not be

ignored and that the interdependence of agricultural operations on one another are thoroughly understood. It should never be thought that heavy manuring alone will give good results in the absence of sufficient water or if sufficient water and manure have been provided the crop will grow well without interculture. In other words the profitable limit of application of any one factor is determined by the presence of all factors in a balanced form. A proper combination of all these factors, *i.e.*, manure, water, hoeing, etc., is essential for producing the optimum condition for growth. Experiments conducted under schemes financed by the I. C. A. R. show a wide range of requirements. Trials at Padegaon in the Bombay Presidency indicated that there at least the top limit of nitrogen manuring was not reached even with an application of 300 lbs. nitrogen per acre as a topdressing and 600 lbs. nitrogen per acre was now being experimentally applied. At that station, on the other hand, it was shown that 50 lbs. of nitrogen as a topdressing per acre fell short of requirements of the sugarcane crop. At the same station, largely based on the previous experiments at Manjri, the optimum dose for topdressing has been considered as 150 lbs. of nitrogen per acre in addition to green manuring. In 1934-35 the relative efficiency of the 75, 150 and 300 lbs. nitrogen topdressing treatment from the standpoint of yield was worked out to be 0.8, 1, 1.5. Periodical brix readings practically showed no difference between 75 and 150 lbs. nitrogen in two varieties, *i.e.*, Pundia and POJ-2,878, even from the early stages, while with 300 lbs. nitrogen it was always two degrees lower up to the last date of sampling (26th January 1935). Delay in maturity with 300 lbs. nitrogen was quite evident. In Bihar in 1934-35 100 lbs. of nitrogen per acre appeared to be the best dose for sugarcane under conditions obtaining in Patna while anything more than 60 lbs. nitrogen per acre was reported to be definitely uneconomical on heavy soils in South Bihar. At Chota Nagpur, 80 lbs. nitrogen per acre gave heavy yields on the departmental farms. At Shahjahanpur, in the United Provinces, in an experiment conducted for three years (1932-35) to find out the most suitable quantity of nitrogen for sugarcane, ammonium sulphate, castor cake and farmyard manure calculated to supply 60, 120 and 180 lbs. of easily available nitrogen were added per acre. 120 lbs. showed the best result. A greater quantity increased the yield but reduced the sucrose and delayed the maturity of the crop. At Anakapalle (Madras) in 1934-35 and 1935-36 with 50 lbs. nitrogen regarded as the normal treatment and its yield taken as equivalent to 100 the yields of jaggery from treatments of 25, 50, 75 and 100 lbs. nitrogen per acre showed higher yield with 100 lbs. nitrogen (Table VII). In the Punjab in an experiment to find out the optimum dose of nitrogen per acre, and which of two manures, *i.e.*, sulphate of ammonia or Toria cake, could be used with advantage to substitute half the dose of nitrogen in farm-yard manure generally applied by farmers, two years' experiments showed that 140 lbs. nitrogen per acre was a reasonable dose on soils of minimum fertility. The dose of 140 lbs. of nitrogen per acre gave better and more economical returns when applied half in the form of farmyard manure and the other half in ammonium sulphate or toria cake instead of applying the whole dose in the form of farmyard manure. Manuring also depended on the variety of the cane. Thick (Pounda) canes and hard late-ripening well-standing canes like Co.-331 could stand a bigger dose than 120 lbs. in Northern India while for a comparatively soft cane of bad lodging habit like Co.-312 about 100 lbs. per

acre was found to be the optimum rate. Poor varieties like C.-244 did well with only about 60 lbs. nitrogen per acre or even less.

At Palur (Madras) experiments for five years ending 1932-33 indicated that the local standard variety 'Fiji B' responded most to heavy manuring of 200 lbs. nitrogen per acre in the shape of oil cake and sulphate of ammonia in the proportion of three to two.

At Padegaon (1935-36) an experiment to test the best quantity of nitrogen as topdressing to the cane crop, in addition to the green manure (with sann) before cane revealed the varietal characteristics as regards feeding habits of two cane varieties. 75, 100, 150 and 200 lbs. of nitrogen were applied to two cane varieties Pundia and POJ-2878. The results of the experiment showed that 150 lbs. nitrogen top-dressing was not a balanced dose and economical for all seasons in both the varieties even though in a normal season very little difference was shown against the higher dose. The economical differences in the final product with heavier dose were higher in the case of Pundia than in POJ-2878.

(b) *Combination of different forms of nitrogen.*—Turning now to the question of the *form* in which nitrogenous manures should be applied, there is a general consensus of experimental results to show that part at least of the nitrogen should be given in the form of an organic manure. Such organic manures are farmyard manure, oil-cakes, green manure or composts. Green manure has received a fair amount of attention and is in fact a normal part of sugarcane rotation in certain areas, e.g., the Bombay-Deccan, largely as the result of the early work of the Manjri Sugarcane Station and also in the United Provinces. Cheapness and availability are also to be taken into account when considering the type of manure to be applied. Dung, one of the obvious indigenous means of increasing fertility, is largely used as fuel. Oil cakes and artificial fertilisers play an important part in intensive farming and are undoubtedly of proved economic value in sugarcane cultivation but may be costly. None of these therefore can be looked upon to provide the ready means of building up impaired fertility so cheaply as green vegetable matter produced on the land itself. The results of various experimental trials show that application of artificials alone is not good both from the point of view of yield and purity of sucrose. There are also evidences of differential response of varieties to different combinations of nitrogenous manures.

At Padegaon in 1935-36, to test the best combination of different quantities of farmyard manure 10,000, 20,000 and 30,000 lbs. of it in combination with 50, 100 and 150 lbs. of nitrogen as top-dressing in each case were applied to varieties Pundia and POJ-2878. Results indicated that, from the economic point of view, it was not safe to reduce the nitrogenous top-dressing below 150 lbs. and the organic manure below 20,000 lbs. The different quantities in nitrogenous top-dressing and organic manure did not cause any marked variation in sucrose in the cane. 30,000 lbs. organic manure showed marked differences over the lower doses in the case of Pundia but no difference was noticeable in POJ-2878. This was probably due to the better feeding habit of POJ-2878. At the same station, the artificial fertilisers—sulphate of ammonia, nitrate of soda, nitrate of potash, calcium cyanamide in combination with an equal amount of cake were tested, the total quantity of nitrogen being 150 lbs. as top-dressing in

the proportion of 50 per cent. from fertilisers and 50 per cent. from cake in each case. The trend of the result was the same as in 1934-35, i.e., there was no marked difference between the different artificials. Also the application of the whole quantity in the form of sulphate of ammonia alone gave significantly lower yields. Increasing the proportion of sulphate of ammonia in the standard Manjri dose because of its low cost did not thus seem to be advisable. In 1935-36 a useful compost was made from cane trash by making long surface heaps and using cow-dung and gurhal ash as starter and compactor. The heaps were watered and received turnings. The cost of the compost worked out at Rs. 1-5-0 per ton (far less than farmyard manure) with an analysis of nitrogen 0.63 per cent. P_2O_5 0.65 per cent., K_2O 3.35 per cent. At the Imperial Agricultural Research Institute, Pusa, a complex experiment was initiated during the year 1935-36 with eleven treatments (including a control) and with three standard varieties—Co.-210, Co.-213 and Co.-331. The field was green-manured in the Kharif season of 1934. Treatments per acre were (1) Farmyard manure ten tons, (2) village bulk manure (farmyard manure) ten tons, (3) Farmyard manure fourteen tons, (4) Cattle standings 14 tons, (5) River silt 28 tons, (6) tank soil 28 tons, (7) standard manure (forty lbs. N. as rape cake and 50 lbs. P_2O_5 as super phosphate), (8) complete minerals (40 lbs. N. as ammonium sulphate, 50 lbs. P_2O_5 as superphosphate and 40 lbs. K_2O as pot. sulphate), (9) superphosphate 75 lbs. P_2O_5 , (10) Ammonium sulphate 80 lbs. N. and (11) No manure control. The superiority of farmyard manure and standard manure was established and on the whole Co.-331 gave better results than Co.-210 which in its turn was found better than Co.-213. At Shahjahanpur in an experiment for three years (1932-35) to find out the best combination of nitrogenous manures for sugarcane in the absence of green manuring, the applications tried were castor cake alone, castor cake plus ammonium sulphate, farmyard manure plus ammonium sulphate and farmyard manure alone, each treatment supplying 120 lbs. nitrogen per acre. The results showed that castor cake was definitely superior to no manuring and to farmyard manure. The difference between castor cake, castor cake plus ammonium sulphate and farmyard manure plus ammonium sulphate was not significant. Castor cake plus ammonium sulphate and farmyard manure plus ammonium sulphate were equal. Farmyard manure was inferior to all other treatments except no manuring. With regard to the behaviour of these three manures when applied singly in a field green-manured with *sanai* it was found that there was no significant difference between them although each showed better result than green-manuring alone. Where green-manuring could not be given, castor cake alone was indicated for that year if cheap and readily available or, alternatively, cow-dung supplemented by a later dose of ammonium sulphate. The analytical figures in the lately showed that the percentage of sucrose and purity was highest under control (no manure except green manure) and farmyard manure. The percentage sucrose was invariably found to be lower in cases where ammonium sulphate was added. In 1934-35 a comparison of organic *versus* inorganic manure did not show any significant difference in yield between the two treatments but the analysis figures were markedly in favour of organic manure. At Muzaffarnagar in 1935-36, 60, 120 and 180 lbs. nitrogen were added to three varieties, i.e., Co.-244, Co.-300 and Co.-312 in a replicated trial. While the yield went up as a rule with the

increased nitrogen, the response was not very marked beyond 60 lbs. nitrogen per acre. The highest yield obtained was of Co.-312, with 180 lbs. nitrogen which gave 36.3 tons per acre. Other experiments at this station indicated the advisability of utilising a combination of both organic and inorganic manures. The North Bihar manuring schedule, evolved as a result of long experience is 40 lbs. nitrogen plus 30 lbs. P_2O_5 per acre on the top of green manure. This is needed to maintain soil fertility and ensure high cane and sugar yields. The plan recommended is to apply half this quantity at planting and the other half at earthing just at the break of monsoon. In South Bihar 60 to 100 lbs. of nitrogen is being applied and investigations to work out the standard schedule are in progress. It is further found that applications of castor cake to light soils deficient in moisture are detrimental and it is necessary before applying to compost the cake or keep it moist by sprinkling water to counteract this harmful effect.

In Assam 300 maunds of cow-dung (250 maunds of cow-dung = 100 lbs. of nitrogen) plus 100 lbs. of oil cake (mustard cake) was found to be the best manurial dressing for plant cane. This is the standard manure for plant canes adopted on the Jorhat farm. For ratoon canes it has been found there that it is not sufficient to rely on the residual effect of manuring of plant cane but that ratoons themselves have to be manured. 200 maunds of cow-dung plus 200 lbs. of oil cake was found best and was adopted as the standard dose for ratoons. A manurial experiment with a common dressing of 1,000 lbs. of oil cake per acre and different doses of 100, 200, 300 and 400 lbs. of aminophos did not give encouraging results. Another manurial experiment with (a) cow-dung, (b) oil-cake and (c) half the amount of each, applied in (a) and (b) applied at three different times, i.e., (i) all applied in trenches before planting, (ii) half applied in trenches and other half at the time of first earthing, (iii) half applied in trenches and one quarter applied during first earthing and the other quarter during the second earthing showed that the mixture of cow-dung and oilcake was the best, and the earliest application in trenches before planting was better than two later applications, which were identical in effect. Manurial trials at Palur (1934-35) indicated that sodium nitrate was not as good as a mixture of ammonium sulphate and oil-cake. In the N.-W. F. Province (1935-36) in an experiment to compare silt with farmyard manure it was found that in point of yield as well as economically silt was better than farmyard manure. The variety on which the experiment was tried was Assam red.

(c) *Manuring with other elements.*—The effect of phosphoric acid and potash is very varying. Phosphoric acid gave promising responses in Bombay and North Bihar but no effect was seen in the Punjab and the United Provinces. There are indications, however, of these elements increasing the percentage of sucrose and purity when applied in combination with higher doses of nitrogen. Indications of their increasing the rind hardness of the cane and making the plant vigorous to stand the attack of insect pests are also available. Experiments at Padegaon (1935-36) showed that the addition of 100 lbs. of P_2O_5 at planting time to Punida cane in addition to the usual standard dose of nitrogen top-dressing with sann hemp before cane gave results which increased the tonnage by nineteen per cent. with high gul to cane recovery. While P_2O_5 in the form of superphosphate gave promising response, field experiments with

sulphate of potash and nitrate of potash resulted in no improvement over the yield per acre or sugar content of the cane. At Jullundur (Punjab) in an experiment in 1935-36 with a basic dose of ten tons of farmyard manure the following treatments were replicated :—

1. 100 lbs. of N. in the form of ammonium sulphate.
2. 75 lbs. of P_2O_5 in the form of super-phosphate.
3. 100 lbs. of K_2O in the form of sulphate of potash.
4. Complete fertilisers (100 lbs. of nitrogen + 75 lbs. P_2O_5 and 100 lbs. K_2O).
5. 150 lbs. K_2O in the form of sulphate of potash.
6. 200 lbs. of K_2O in the form of sulphate of potash.
7. Control.

There was no response with either potassic or phosphatic manures but in treatments Nos. (1) and (4) where 100 lbs. of nitrogen were applied in the form of sulphate of ammonia, the yields were significantly high. The chemical analysis results were, however, in favour of those that received higher doses of potash. At Shahjahanpur in the United Provinces, experiments conducted for three years (1932-35) did not show any effect of either P_2O_5 or K_2O on the yield of cane but the quality improved only in combination with higher doses of nitrogen, i.e., 200 lbs. or more. In a trial at the Government Farm at Gorakhpore (1934-35) where super-phosphate and sulphate of potash were added at the rate of 60 lbs. per acre each a combination of nitrogen and phosphoric acid gave the best yield while in another trial in which nitrogen and superphosphate were kept constant at 120 and 60 lbs., respectively, and K_2SO_4 was given at a varying doses of 100 lbs., 200 lbs., 300 lbs., 400 lbs. and 500 lbs. per acre the differences in yield were found between different applications during the first year, the larger doses giving an increased yield but no marked increase was noticed during the second year. At Anakapalle (1934-35) the combination of nitrogen with potash appeared to be better than a combination with phosphoric acid. The North Bihar manuring schedule, already mentioned, involves the application of 40 lbs. of nitrogen plus 50 lbs. P_2O_5 per acre on the top of green manure.

Rind hardness of cane was also measured in terms of lbs. pressure by an instrument in various treatments at Shahjahanpur (1935-36). Potash definitely increased the hardness of the rind while phosphate had no such effect. The cane definitely became softer as the dose of nitrogen increased. This increase in the strength of the mechanical tissue due to potash may be helpful in warding off attacks of insects. In entomological trials at Muzaffarnagar Farm there were also indications of decrease of top-shoot borer attack in beds manured with superphosphate and sulphate of potash. At Padegaon there was a significant fall in the top borer attack in 1936 compared with the previous year, due to phosphatic manure which induce early vigorous tillering.

In Assam liming experiments in acid soils at the rate of 10, 20, 30 and 40 maunds of lime per acre with a common application of the standard nitrogenous manuring of 300 maunds cow-dung plus 1,000 lbs. of mustard cake per acre to all the plots showed that the highest application of 40 maunds of lime gave significant increase over no application. Ten and

twenty maunds had little effect but 30 maunds gave an increase not significant over no application. The increase of .5 tons of sucrose with 40 lbs. application of lime over no lime was just sufficient to meet the cost of the lime used and as such the experiment was not of much economic value. It had however academic value for the acid soils of Assam and the residual effect of liming in the ratoon canes as well as the part it was likely to play in the usual rotation of sugarcane lands. In the Punjab gypsum did not show any significant effect on either quality or quantity in trials conducted for two years.

(d) *Time of application of manures.*—The general consensus of experimental results shows that organic manures should preferably be applied well before planting cane so as to give time for their nutritive elements to become available. Ammonium sulphate and other quick-acting nitrogenous manures may be applied with or without oil cake at planting, at germination, or later at tillering. A replicated trial conducted for three years (1932-35) at Shahjahanpur showed that the quick acting inorganic manures should be applied during the early period of the life of the plant, i.e., either just before sowing or after germination or at the time of tillering. Later applications were not found useful. Further trials to find out whether the dose should be given in one or two applications, clearly indicated that it depended largely on the state of fertility of the land. The most important point was that the food should be available at all critical periods of growth. In Assam (1935) in a manurial experiment with Co-280 with the manures at three different times it was observed that the earliest application was decisively better than the two later applications which were similar in effect both with regard to yield of cane and total sucrose. The differences in the percentage of sucrose in juice with different times of application were not significant. In North Bihar 40 lbs. of nitrogen and 50 lbs. of P_2O_5 are recommended to be applied half at planting and the other half at earthing first with the break of monsoon.

VI.—Green manuring.

The importance of green manure crops for supplying organic material to the soil is great and considerable attention has been given to the trial of different crops and methods of green manuring in different provinces. The one great factor in its favour is that the cultivator can produce it on his own land and has not to rely on an outside agency. The cheapness of green manure is another reason for its growing popularity. It has been found to be a very useful means of renovating the dry tracts of Deccan brought under irrigation. Sann (*Crotalaria juncea*) has so far been found to be the most useful crop for green manuring both in the tropical and sub-tropical India. It is sown in June and the experiments in the north have shown that the whole plant buried after 50 days growth gave the highest conservation of nitrogen. At Padegaon in order to see which crops would supply the maximum green matter and which months were favourable for sowing these crops six species* sann, dhaincha, udid, black kulthi, matki

*Scientific names of six green manure plants of important species :—

1. *Crotalaria Juncea* (Sun-hemp).
2. *Phaseolus Mungo* (Urid).
3. *Sesbania Aegyptia* (Dhanicha).
4. *Tephrosia Purpurea*.
5. *Cyamopsis psoralioides* (Guar or Kulthi).
6. *Dolichos biflora*.

and *kulthi* were sown in April, May, June, July and September for the last three years (1933-36). It was found that Sann and Dhaincha supplied maximum green matter, sann was ready for burrying earlier by about three weeks than Dhaincha. Next to these two in the matter of quantity of green matter was *udid* and it was even earlier than Sann. The rest were not suitable. The best months for sowing to have maximum green matter in the case of sann, dhaincha and *udid* were June and early July. If sown at other periods, the crops were affected by insects, September sowing was affected by mildew. In another experiment to test the efficiency of a leguminous weed locally called Patada Shevra (*Alysicarpus belgaumensis*) which was found to increase under irrigation it was found that it matured later than Sann and gave nearly the same yield of green matter as sann in both medium and heavy soils. Extensive studies on the use of sann hemp as green manure crop for sugarcane were carried out at Shahjahanpur. Green manuring with *Crotalaria juncea* was found to supply about 60 lbs. of nitrogen to soil of medium fertility. The percentage of nitrogen accumulation in the soil by ploughing in different portions of the plant, i.e., whole plant, tops and roots and by burying in sann of different ages in the first and second foot of the soil were studied throughout the season at regular monthly intervals. The result indicated that the whole plant of sann was best, followed by top portions of the plant and roots. 50 days growth gave highest conservation of nitrogen followed by 60, 40 and 30 days growth. The yield of cane varied according to the accumulation of nitrogen in the soil, the greater percentages giving greater yield and *vice versa*. The results of experiments of green manure and no manure conducted at Shahjahanpur (1934) on proper replicated basis showed yield of sugarcane in green manured beds as 891.66 maunds per acre as compared to 621.74 under non-manured beds. The extra profits secured by green manuring per acre amounted to about Rs. 68. The prevailing market rates and percentage nitrogen with the price per lb. of nitrogen of the various organic and inorganic manures commonly available in sub-tropical India as compared with sann are as under :—

Manure.	Market rate 1937.	% of Nitrogen.	Total nitrogen contained in Col. 2.	Annas per lb. of Nitrogen.	Remarks
1. Castor cake	Rs. 1/1/6 per maund.	4.0	3.29 lbs.	5.32	
2. Neem cake	Rs. 1/4/- per maund.	6.0	4.92 lbs.	4.06	
3. Dung (Farmyard manure).	Rs. 1/4/- per cart of 15 maunds.	.46	5.679 lbs.	3.522	
4. Ammonium sul- phate.	Rs. 4/11/- per bag of 78 lbs. net.	20.6	16.068 lbs.	4.668	
5. Green manuring with <i>Crotalaria</i> <i>Juncea</i> .	Rs. 2/8/- per one maund of seed re- quired for one acre.	Approximately 45 lbs. of nitrogen per acre (on cul- tivated lands).	45 lbs.	.88	

The figures indicate that price per lb. of nitrogen is cheapest in *Sunn*. The effect of green manuring on juice quality was also examined and it was almost invariably found that percentage sucrose and purity was higher in the untreated plots than in treated ones.

At Pusa experiments on green-manuring with berseem on sugarcane ratoon were carried out for two years. Treatments per acre were (1) berseem green manure, (2) standard manure (40 lbs. N. as rape cake and 50 lbs. P_2O_5 as superphosphate), (3) ten tons farmyard manure, (4) twenty tons farmyard manure and (5) complete minerals (40 lbs. N. as Ammonium sulphate, 50 lbs. P_2O_5 as superphosphate, and 40 lbs. K_2O as potassium sulphate). Treatment No. 4 gave the best results which were found to be better than those with treatment No. 1 in both years. In the North-West Frontier Province (1935-36) experiments in green manuring consisted of (i) berseem ploughed in *versus* fallow, (ii) shaftal ploughed in *versus* Arhar (*Cajanus indicus*) removed, (iv) Sann hemp ploughed in *versus* sann hemp removed, and (v) Guara (*Cyamopsis psoralioides*) ploughed in *versus* guara removed. Different varieties were used for different trials. Shaftal green manure gave somewhat better results than the rest.

VII.—The use of molasses as manure.

The experiments have mostly been carried out in the United Provinces where the results of its application have given the following results:— (1) Beneficial results are obtained only when molasses is applied to the soil some time before sowing the crop and well mixed with it by watering and hoeing and keeping the soil well aerated. (2) The outturn of planted cane increases with the increase in the quantity of molasses applied two months before planting and at the sowing time but the yield decreases if applied late at tillering time. (3) The juice of planted canes treated with molasses generally show increase in percentage sucrose. (4) The juices of ratoon canes treated with molasses are generally poorer in sucrose than those of untreated ones but the tonnage of the former is higher which more than offsets the poorer quality of juice. (5) The outturns of different subsequent crops obtained from the residual effects of molasses and other manures show the superiority of molasses over others in this respect. (6) About ten tons per acre has been found to give good results with plant cane although about 90 maunds under the present condition of molasses selling at 0.40 per maund seems more economical. Recent researches of Professor Dhar at the Allahabad University indicate its possibilities as a material for improving alkaline and *usar* lands. Further investigations are required to confirm the results achieved so far. At Shahjahanpur experiments carried out for three years (1932-35) on Co-300 and Co-331 with 90, 180 and 270 maunds of molasses applied three times, i.e., two months before planting, at planting and two months after planting the cane (i.e., at tillering) showed the highest yield with 270 maunds applied two months before planting. After three years experimentation with molasses alone 270 maunds were combined for the last two years with 60 lbs. Nitrogen in the form of organic (castor cake) and inorganic (ammonium sulphate) nitrogenous manure. No increase in yield was found by this application. Another experiment was carried out in which bagasse was soaked in a suitable quantity of molasses in order to facilitate transport. In both cases molasses was applied at the rate of 250 maunds per acre against no manure applied. The molasses applied as such gave 954.7

maunds of cane per acre, bagasse soaked in molasses gave 302.2 maunds and the untreated plot gave 775.47 maunds. The no-manure plot showed the highest percentage of sucrose, the figures being no manure 16.15 per cent., pure molasses 15.88 per cent. and bagasse soaked in molasses 15.98 per cent. The accumulation of percentage of nitrogen in the soil with different treatments was studied in the laboratory by analysing soil samples from different beds at regular monthly intervals throughout the season. Samples were taken from both first and second foot. The latter corresponded with the accumulation in the first foot although the percentage nitrogen was comparatively smaller. The conservation of nitrogen was greater in the plots receiving a dose of 270 maunds of molasses per acre followed by 180, 90 maunds and control (no molasses). The yield of cane corresponded with the percentage of accumulation the greatest percentage giving the highest yield and *vice versa*.

At Cawnpore (1933-34) molasses were applied at the rate of six and twelve tons per acre two months before and two months after planting the crop (Co.-213). The twelve tons treatment gave better yield of cane and sucrose than the six tons treatment. The residual effect of twelve tons was also better and this increase was statistically significant. To see the effect of molasses on ratoons experiments were conducted at Gorakhpore, Cawnpore and Muzaffarnagar with Co.-213. Results are shown in table (XIII). Molasses gave a higher yield of ratoon canes in all cases in Gorakhpore and Cawnpore and compared favourably with fertilisers at Muzaffarnagar. This increase was statistically significant as compared to the control. Percentage sucrose was poorer than the untreated or otherwise treated plants in all cases except one.

At Anakapalli groundnut cake, ammonium sulphate and Pillipesara (*Phaseolus trilobus*) were tried in comparison with different doses of molasses with Co.-213. Molasses gave as good yields as groundnut cake.

VIII.—Irrigation.

Just as with manures, so with irrigation there is great variation in practice due to variation in soils, rainfall and the price of irrigation water. Accurate irrigation experiments are more difficult to lay out than manurial experiments as there must be an accurate water measuring device for each plot. There have been, of course, irrigation experiments in which water was roughly measured and these have a certain value as indications. Studies of relative requirements of water by different varieties have been carried out and these gave definite indications of suitability of different varieties to different conditions. Irrigation experiments were as a rule combined either with manurial experiments or with varietal experiments or with both. At Annakapalle in 1935-36 comparisons were made between blocks receiving normal irrigation (seven irrigations), winter irrigation (three irrigations), hot weather irrigation (two irrigations) and no irrigation. Although winter irrigation and normal irrigation were better than hot weather irrigation and no irrigation, there was very little difference between the last two. In 1934-35 normal irrigation was better than all the other three, giving yields of 19 per cent., 11 per cent. and 12 per cent. higher than no irrigation, cold weather irrigation and hot weather irrigation respectively. At Annakapalle about 6 inches rain is received in the hot weather—February to May, 20 inches during the south-west monsoon and 15 inches during the north-east monsoon—total 41 inches. This is considered sufficient to grow the sugarcane crop provided it is planted either

with the help of the hot weather rains or the first south-west monsoon showers. An irrigation experiment at Palar showed that Co.-213 resisted drought best and that Co.-285 and Co.-243 were also promising whereas POJ-2878 did not behave satisfactorily under these conditions. At Padegaon irrigational investigations to test the effect of different quantities of water—70, 95, 120 and 130 acre inches of water—with two varieties (Pundia and POJ-2878) were conducted on the January planted crop for three years with the manurial treatment of 150 lbs. nitrogen top-dressing applied according to the Manjri standard method. The results showed 95 acre inches to be the optimum for this dose of top-dressing while quantities above 120 inches were found definitely injurious to crop growth leading to consequent fall in yield. The dose of 70 acre inches was found to be insufficient as in the event of the late approach of monsoon it definitely fell short of the crop requirements. On the other hand heavy irrigation of 130 inches necessitated higher manuring as it led to both leaching down of the soluble nutrients and the checking of the activities of the soil microflora. From the standard of *gul* however higher waterings were found to be beneficial as these hastened maturity resulting in improved quality of *gul*. A better coloured *gul* with reduction in the percentage of alkali salts was obtained by the treatment of 130 inches compared to all the lower waterings. The water requirement of the crop was found not to be the same throughout the growth cycle of the plant. It was highest during the growing period and flowering stages and least during the maturity stage. Experimental evidence had also shown that the optimum rate of 95 inches could be achieved by keeping a constant ten days' irrigational turn varying at the same time the quantity according to requirements. Shortening the interval during the summer to an eight days' turn did not result in any improvement, while delaying the irrigational turn beyond ten days (fortnightly irrigation) during summer was found to check the growth of the crop to a very great extent, and even regular treatment later on did not make up the loss. On the other hand allowing the crop to reach the permanent wilting stage once during its life cycle either in April or May did not affect the yield. The period required to attain this condition varied between 21 and 45 days depending upon the variety and the physical condition of the soil. It was found that irrigation at the end of this period produced new fresh roots which gave a fillip to the crop and led to its rapid growth. This result is of great practical value in the case of shortage of water during summer before the onset of the monsoon. At Shahjahanpur where the water was measured with the help of a leaf-recorder an experiment carried out for three years (1932-1935) indicated that increase in the yield of sugarcane was proportional to the frequency of watering rather than to the quantity given at each watering. 80,000 gallons per acre per irrigation gave better results than either 60,000 or 1,00,000 gallons. It further showed that the requirements for trenches and flat sowing were not the same. In trenches a larger number of irrigations was required with comparatively small quantities each time while in the flat relatively fewer irrigations with larger quantities at each irrigation were needed. It was found imperative that on an average soil the grower should be absolutely certain of obtaining water once in 21 days between the middle of May and the normal time of the break of the rains (about the last week of June). In later trials (1934-1936) the optimum quantity of water, i.e., 80,000 gallons of water was given three, four, five, and six times each combined with 60, 100, 200 lbs. of N. per acre. The

yield increased according to the number of times water was given, the results being very striking in this respect, *e.g.*, when the water was given three times the yield with 100 lbs. of nitrogen was 691.82 maunds while when water was given six times the yield of cane per acre was 893.92 maunds per acre of cane (Table XV). The quality of juice deteriorated with increase of nitrogen, but the number of irrigations had had no effect on it. Another experiment at the same station investigated the effect of giving 240,000, 360,000 and 540,000 gallons per acre per year with two manurial treatments, *i.e.*, no nitrogen and 100 lbs. of nitrogen per acre. Along with this were combined three sowing dates—February 1st, March 8th and April 12th. In the case of the series receiving nitrogen, the maximum weight was produced with the earliest sown plant when most water was given. There was decreasing efficiency of both nitrogen and water with delay in the time of planting. In the Punjab irrigational trials with improved varieties for two years, *i.e.*, from 1934 to 1936 at Risalewala with liberal watering (irrigation given after every 10 to 12 days) and restricted watering (after 15 to 18 days) showed significantly better results in favour of liberal watering. The results are summarised below :—

Average cane yields per acre in maunds.

	Co.-213.	Co.-223.	Co.-285.	Co.-312.	Co.-313.
<i>1934-35.</i>					
(i) Under liberal watering	716.6	710.2	910.4		832.6
(ii) Under restricted watering	535.4	560.4	787.0		705.2
(iii) Percentage increase over restricted watering	33.8	26.5	15.7		18.0
<i>1935-36.</i>					
(i) Under liberal watering		588.0	733.6	719.2	574.0
(ii) Under restricted watering		464.8	620.0	649.2	497.6
(iii) Percentage increase over restricted watering		26.5	18.3	10.7	15.3

Co.-213 and Co.-223 responded to liberal watering more than Co.-285, Co.-312 and Co.-313 and the former varieties should therefore be grown only in localities which have ample irrigation facilities. Reduction in yield of Co.-285, Co.-312, Co.-313 as a result of restricted irrigation was smaller than in the case of Co.-213 and Co.-223. In other words the former group can stand drought better. Hot weather irrigation of cane resulted in higher cane and sugar yields. The growth records showed that irrigations given during this period provided the plant with an equipment of foliage and surface roots that proved serviceable immediately on the advent of the rains, thus ensuring quick response and faster growth. Where cane received no irrigation during the hot weather it reached the rainy weather poorly provided with requisite foliage and lateral roots so that its phase of quick growth was delayed—a feature of considerable importance in these parts where the main growth season was generally restricted to rainy weather. Study of lateral distribution of irrigation water with a view to deciding upon the number of border rows to be provided in irrigation experiments showed that it extended up to about 54 inches on the free side of the best planted row on the light high land, suggesting a border of 2-3 rows on either side.

In Bihar.—In an experiment (1935-36) to study the relative requirements of water by different varieties at Museri it was found that the average requirement was about 43 inches of water in the season including the direct evaporation losses, and that Co.-331 made the most economical use of water as compared to other varieties studied.

IX.—Soil investigations.

Extensive soil work of varied nature was in progress during the last five years (1932-37) at Padegaon. The soil classification was done according to the Russian method. In this a vertical section of the soil (called a *profile*) was taken as the unit of study. Nine types of soils which are named A to I have been recognised. Out of these, six, i.e., A, B, D, G, H and I were found to be suitable for cane growing under perennial irrigation and three unsuitable. Amongst the six it was found that some will respond to high manuring for the production of higher yields better than the others. Soil fertility surveys were also conducted on the Nira Left Bank and the Godavari canals where the soils have had cane for forty and twenty years respectively. The object of these surveys was to study how the soils have behaved—whether they have improved or deteriorated under cane growing. These investigations showed that soils deteriorated due to (i) high carbon nitrogen ratio in the soil, sodium-colloid formation and hydrogen-colloid formation, the first-named factor being responsible for about one-third of the total damage under irrigation. Investigations were carried out on the reclamation of *chopan* (a typical alkali soil) soils and on soil degradation in general. The reclamation of *chopan* soil was tried (1935) with applications of sulphur, gypsum and farmyard manure in various combinations, followed by irrigation and drainage. The treatment brought about a considerable loss of exchangeable sodium and in total base saturation capacity of the soil. A crop rotation of cane-cotton-berseem was found to reduce sodium saturation in these soils. Interesting results are now available on the causes of non-response to farmyard manure in certain soils and their relationship with the soil microflora. Suggestions have been made for simpler means of amelioration of spoilt lands. Experiments with different nitrogenous, potassic and phosphatic fertilizers showed that the available portion of these fertilizers was released during the first six months after their application and very little could be washed out from the soils after that period. There was fixation of nitrogen in the farmyard-manure-treated plots whereas there were losses of nitrogen in the case of the rest of fertilizers. A study of the Punjab cane soils made in 1933-34 and 1934-35 showed that the nature and the amount of water soluble salts were markedly different from those of the United Provinces and Bihar but the amount of exchangeable calcium was lower and this might be one of the causes of inferiority of Punjab canes.

X.—Diseases of sugarcane.

The common diseases of the sugarcane crop are mosaic, red rot, and fungal and bacterial diseases such as smut and stinking rot. Red rot is now no longer of importance since the process of set selection eliminates any danger from this disease. The disease to which most attention has been given in recent years is the so-called mosaic disease. It is a virus disease producing pallor and mottling of the leaves. It is now known to be capable in some countries of causing great reduction in yields. Several

Strains of sugarcane mosaic virus appear to exist in India. Carefully repeated tonnage experiments carried out year after year at Pusa show that there even a very high percentage of mosaic does not reduce the yield by more than ten to fifteen per cent. It can be effectively controlled by roguing and selection of sets. In the United Provinces in 1931-32 and 1932-33, Co.-313 although of considerable promise as one of the high yielders, under good farming conditions was withheld from introduction as stocks at most farms were found to have mosaic. Stinking rot in its early stages is characterised by sudden wilting and drying up of the top leaves followed by rotting of the cane. The spread of the disease is favoured by hot and moist weather. Selection of planting material is the only possible remedy of controlling the disease. Only the most healthy and vigorous canes without any blemishes should be used for planting. The two cut ends of each individual set should be examined and those showing even traces of redness of any sort should be discarded. Surveys have been carried out on the sugarcane growing tracts in India and much useful information has been accumulated as to the susceptibility or resistance of different cane varieties both to mosaic and to fungal and bacterial diseases. The information is published in Miscellaneous Bulletin No. 10 of the Imperial Council of Agricultural Research.

Pests may be divided into two groups according to the nature of the damage they do, *i.e.*, I. External pests, *e.g.*, (i) white ants, (ii) white fly, and (iii) Pyrilla, and II. Internal, *i.e.*, moth borers affecting the top shoot, stem and root and named after the portion of the plant which they damage. White ants are one of the greatest enemies of sugarcane and cause considerable damage. Their ravages begin as soon as cane sets are planted. In a newly planted crop the cut ends and eye-buds are the first places of attack. Later on they destroy the whole set. Their attack can be easily differentiated from other pests by the fact that the plants infested with white ants begin to dry up. In the United Provinces copious irrigation, application of crude-oil emulsion in irrigation-water at the rate of five seers per acre, application of neem cake (20 maunds per acre) applied a fortnight before sowing and limewash as an overnight dip gave considerable protection. Coal tar painted on ends gave sufficient protection at Muzaffarnagar farm but were not found useful at Mushari in Bihar, where it adversely affected germination. In the Pusa method of sugarcane plantation immersing the sets in coal tar water before planting gave temporary immunity against white ants to some extent.

White fly is an important pest of sugarcane in water-logged and low-lying areas. Removal of infested leaves during July and August, discouraging ratoons, avoiding growing of the crop in waterlogged areas, early harvesting of infested crop and removing and burying cane trash were found helpful at Muzaffarnagar.

Pyrilla does a considerable amount of damage to the sugarcane crop. The hopper by draining away the sap weakens the plants at a critical stage of their growth and the insect in favourable season produces as many as five broods in one year. Experiments at Muzaffarnagar showed that it was capable of reducing the sucrose content of the juice by about 2½ per cent. or even more. Bagging of adults and nymphs by field nets, collection of egg masses and stripping leaves of canes not required for seed purposes after August were found helpful remedial measures.

Internal pests, i.e., borers.—The three important borers are top-shoot borer (*Scirpophaga nivella*), the stem borer (*Argyria sticticarpis* and *Diatraea venosata*) and the root borer (*Emmalocera depressella*). The damage due to these borers is very considerable. At Padegaon there was a significant fall in the top borer attack in 1936 compared with the previous year due to phosphatic manure which induced early vigorous tillering. Early planting in October and November was also found to minimise the attack. At Dacca all canes suffered heavily in 1935-36 from the attack of top and stem borers, no variety being spared. The soil and weather conditions in the red laterite area and where the Dacca farm is situated appeared to encourage insect pests, the attack being 50 to 60 per cent. as against almost nothing in the neighbouring districts of Tippera and Mymensingh. At Dacca station the varieties were divided into four broad groups on the basis of the resistance to insect pests. At Muzaffarnagar treatment by superphosphate and sulphate of potash with Niciphos tended to decrease the top borer attack although cultural operations like early planting and early harvesting, cleaning the field of stubble, discarding ratoons, sowing borer-free sets and resistant varieties and collection of insects and eggs by hand at the right moment, were also found ameliorative. At Jorhat in Assam light traps were used for controlling the top-shoot borer in 1935-36. Parasitisation of these insects was carried out with considerable success in Mysore where the parasite *Trichogramma minutum* has been bred in large numbers in the laboratory and liberated in the cane fields. Two simple cultural methods of borer control have also been adopted. The first is the removal of the first sheath of canes as these contained a large number of borer larvae of varying ages. The second method consists of a light earthing up with a mould board plough when the shoots are a month old, the soil covering the first leaf sheaths. A good irrigation is given soon after this which makes the loose heaped up soil to settle around the shoots. This smothers the larvae and prevents further damage. This light earthing up helps the growth and vigour of the shoots appreciably. It was also found that in addition to improved methods of earthing up, raising of a crop of sann-hemp in the rows of the ratoon plots and ploughing it in when the crop was young, not only kept the moths down but also encouraged vigorous cane growth. Field studies at New Delhi so far indicate that the larvae of the top borer prefer canes which have leaves with thin mid-ribs. At Jullundur the study of the bionomics and control of top borer and pyrilla showed that hand-netting of pyrilla adults and removal of top borer affected shoots along with the destruction of moths and eggs in April and May was helpful in reducing the attack.

XI.—Physiological.

In several of the researches there has been a definite physiological section in which the life processes of the plant were scrutinised in detail. Only results of a few important researches that have some practical bearing are given here.

1. **Weather and growth.**—In Bihar periodic records of height measurements and accumulation of dry matter showed different responses to weather conditions by different varieties. If July rainfall was deficient some varieties suffered a serious check in growth which, in spite of adequate rains in August and September, was reflected in the harvest results. A high correlation between the stage of growth and the effects of the visitation of an unfavourable circumstance was indicated. The practice of

topping of cane before harvest during December showed negligible losses for the first four days recording actual increase in sugar per cent. on the first two days while the losses were markedly pronounced after the first two days during the month of February. Unless therefore the topped cane could be sent to the mill within two days topping should not be resorted to after the end of January in North Bihar.

In the Punjab in studies of preservation of seed material from frost injury, it was found that thick stand of the crop and liberal irrigations before and during frost enabled the crop to resist the frost better. A point of vital importance was discovered that seedlings even when 1½ months old could be successfully transplanted direct into the main field provided this was done before the advent of the hot weather. The mortality was not more than 10—15 per cent. and the seedlings thus transplanted grew vigorously. A positive correlation between germination energy and output of dry matter appeared to exist. The maximum growth was found to occur at pH 6 to 8.

In Bombay a comparison of the cane growth data for the two seasons (1934-35 and 1935-36) showed that the flowering varieties like POJ-2878 were not able to recoup the loss in growth due to adverse meteorological factors during the early grand period stage in spite of favourable climatic conditions later. On the other hand, non-flowering varieties like Pundia were found to correct it to a great extent. Researches in bioclimatics showed that other factors such as velocity of germination and fluctuation in the subsoil watertable exerted their influence on the crop-growth and thus masked the effect of climate to some extent. Humidity was also found to accelerate the activity of the top borer. The incidence of its attack was, however, greatly reduced in case of early vigorous germination. In Madras growth measurements indicated that the maximum growth took place in the rainy season and growth generally stopped by the end of October.

2. *Water, manure and growth.*—In Bombay preliminary experiments on the periodic intake of nutrients during different stages of plant activities and exudation studies showed that the cane plant was capable of absorbing both nitrates and ammonia. Water culture experiments not only confirmed this but further indicated that it preferred ammonia to nitrates resulting in better growth of the crop. Detailed investigations in the movement of soil moisture revealed that from the standpoint of water-requirement the early grand period stage (mid-May to end of June) was the most critical period in the event of the late approach of monsoon and it was at this stage that the treatment of 70 inches fell definitely short of the crop requirements. On the other hand, heavy irrigation of 130 inches necessitated higher manuring as it led to both leaching down of the soluble nutrients and the checking of the activities of the soil microflora. On the manurial side the findings on the periodic mineral requirement of the crop indicated that the intake was very little during the formative stage and very considerable during the grand period stage. As regards the relative importance of the main elements from the standpoint of intake potash came first and phosphate last. From the manurial standpoint, however, nitrogen and phosphate were found to be the most important. In the United Provinces physiological studies in the inter-relationship of nitrogenous manuring, water duty and date of planting on the growth and yield of sugarcane indicated that with low nitrogen in all sowing dates optimum

yield was obtained with medium watering. There was a decreasing efficiency of both nitrogen and water with delay in the time of planting. The studies of mineral intake by the plant showed similar results as obtained at Padegaon and intake of plant food for 100 maunds of cane (including leaves and tops) at the time of harvest in lbs. was organic nitrogen 8.72, phosphoric acid 5.68 and potash 11.76. In North Bihar it was found that when soil moisture fell below 5—7 per cent. in the first part of soil the growth of cane ceased.

3. *Root studies.*—In the Punjab as a result of extensive work it was found that the thickness of the main and other roots and rootlets, the number and length of secondary and other tertiary roots played an important part in making the variety drought and frost-resistant. In Northern Bihar in 1932-33 it was found that the physical properties of soils were more important than the chemical ones in determining the development of root systems. In Madras in 1934-35 observations were made on the root systems of the most important varieties to pick out the best of the types that could resist drought. Under dry conditions Co.-213 and some of the sugarcane sorghum hybrids developed a deep root system and were able to withstand dry conditions remarkably well. Co.-419 and Co.-243 were also equally good in that respect.

4. *Miscellaneous.*—A serious physiological disorder causing yellowness of leaves was greatly helped by the application of iron sulphate solution in the Karnal district. At Mysore it was found that time and development of flowering had a bearing on the sugar value of canes. By noting the beginning of flowering period it might be possible to forecast the yield basing the forecast on the observation of the number of internodes produced at the time of flowering.